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REPORT TO THE 19TH SUPERSONIC TUNNEL ASSOCIATION MEETING ON THE DEVELOPMENT OF THE ~~JET PROPULSION LABORATORY~~ JPL SHOCK TUBE LABORATORY

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ABSTRACT

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The development of the shock tube laboratory at JPL is described from a general point of view. Objectives of the shock tube laboratory are disucssed and pertinent references and photographs are included in the report.

The shock tube laboratory consists of an electrically-heated driver 6-inch tube which has produced shock velocities slightly in excess of 30,000 ft/sec and a cold driver 3-inch tube. In the firm planning stage is a 12-inch piston-heated driver for the 6-inch tube.

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I. INTRODUCTION

One of the objectives of the Jet Propulsion Laboratory (JPL) is to conduct exploratory studies of Mars and Venus by means of unmanned probes. The shock tube laboratory has been created in order to solve some of the technical problems associated with the planetary entry of these probes. The immediate technical problems are concerned with the design of the entry capsule.

The basic physical problem is the rate of heat transfer to the capsule at super-satellite velocities. The shock tube investigations are directed towards the study of three modes of heat transfer. These are convective heat transfer, equilibrium radiation heat transfer, and non-equilibrium radiation heat transfer.

A proper approach to these problems should result in an improved understanding of the dynamics and properties of high temperature gases as well as provid~~ing~~e ~~the~~ engineering answers necessary in the design of an entry capsule. In the design and development of the shock tube laboratory, emphasis has been placed on the attainment of immediate engineering answers. It is felt however that the experimental information obtained will naturally lead to better understanding of the physical phenomena, and that this in turn will lead to original research and experimentation in the field of high temperature gas dynamics.

The desire to have an excellent research laboratory, as well as the desire to rapidly obtain engineering data, has motivated the selection of some of the equipment and instrumentation.

II. DESCRIPTION OF LABORATORY

The shock tube laboratory consists of three shock tubes. These include:

1. ~~Hypervelocity~~ electrically driven shock tube

2. Conventional shock tube with a double diaphragm.

3. Free-piston shock tube

The ~~hypervelocity~~ electric shock tube is the basic research tool that is (currently) being used for the heat transfer studies.

The small conventional shock tube ~~has been~~ used to further the instrumentation of the electric shock tube. The small shock tube has been designed as a quality research tool in addition to its instrumentation function. The free-piston shock tube will be used for basic research in high pressure and high temperature gases.

A. ~~Hypervelocity~~ Electric Shock Tube

The electric shock tube is capable of simulating flight velocity of over 42,000 ft/sec. Basically the electric shock tube consists of a helium driver ~~through~~ into which is discharged the energy of the capacitor bank. The ~~JPL~~ capacitor bank has an energy storage of 120,000 joules and is capable of expansion to ~~5000,000~~ 500,000 joules. This energy increases the temperature and pressure behind the diaphragm. ~~and leads to higher shock velocities than are possible in a combustion shock tube.~~

The design of the shock tube began during the summer of 1962. The electric shock tube was chosen because of its proven capability (see Ref. 1 and 2) in our area of interest and many of the features of the AVCO electric tube were incorporated in the design.

The shock tube has a 6 in. inside diameter and is 40 ft. long. The driver section is 15-in~~ches~~ long by 1 3/8 in. inside diameter. There is a conical transition section between the driver and the driven tubes. Figure 1 shows the complete shock tube and its supports.

Figure 2 is a view of the capacitor bank and vacuum system.

Construction of the shock tube and of the capacitor bank and electrical equipment began in August and September of 1962. During this time the necessary modifications to the building which would house the research facility were initiated. Basic instrumentation for the determination of shock speed and initial pressure was ordered. The vacuum system (see Fig. 2) with a specially designed coutour valve was ordered as well as the capacitors for the energy bank. A distinct effort was made to coordinate these activities so that experimentation could begin at the earliest possible date.

By the middle of December it was possible to begin testing of the capacitor bank and associated instrumentation. The amperage and voltage characteristics of the bank were determined. Shortly after this several static tests were tried with the shock tube driver. These tests indicated that some minor changes were necessary in the liners in order to eliminate grounding difficulties. By January 20, 1963 static testing of the driver had been accomplished. This was a severe proof test of the driver and of the capacitors and electrical cabling. These tests which gave a maximum current of about 150,000 amperes were successful.

At the end of February the driven end of the tube had been assembled and several tests were conducted to correlate diaphragm opening time with the capacitor bank discharge characteristics. These tests showed that the energy discharge had been completed before the diaphragm opened. This would indicate that a more or less uniform gas sample existed behind the diaphragm before the diaphragm opened.

Shock speed instrumentation consisting of photomultipliers were attached to the tube. The initial pressure measurement device which had been concurrently designed and built at JPL was also attached.

Initial convective heat transfer measurements were started early in April, 1963. The maximum shock speed to date has been somewhat over 30,000 fps. This fulfills the earlier design requirement ~~of~~ for a flight velocity of about 42,000 ft/sec.

Thus, 9 months elapsed from the initial design phase to the initial experimentation phase. There is still a good deal of instrumentation development required before equilibrium radiation and non-equilibrium radiation measurements can be made. However, convective heat transfer experiments will continue as this other instrumentation is developed. In the near future photographs will be taken of the shock wave by means of an image converter camera. Meanwhile some of the required instrumentation techniques are being developed on the small conventional shock tube.

B. Conventional Shock Tube

The shock tube has a three-inch inside diameter, with the cold driver being 4 ft. long and the driven tube being 17 ft. long. Helium or hydrogen ~~may~~ can be used as the driven gas. Figure 3 shows the shock tube and some of its instrumentation. It was decided to begin construction of this tube in October, 1962. The shock tube was essentially completed by January 15, 1963. Thin film guages are used as shock detectors. Initial pressure is determined by a Wallace and Tiernan absolute pressure guage. A vacuum system capable of about 5×10^{-4} mm Hg is used with the tube.

The double diaphragm technique (see Ref. 3) has proved quite successful for obtaining reproducible shock speeds.

The development of the sputtered thin-film guages will lead naturally into manufacture of a total radiation cavity guage (see Ref. 4). This cavity guage will be used in the equilibrium and non-equilibrium radiation studies in the electrical tube. The small shock tube has been used for testing the photocells used for the shock speed determination in the electrical tube. Further tests of the monochromators that will be used in the radiation studies will be conducted in the small tube. Several experiments have been started on the transport properties of high temperature gases.

C. ~~Piston~~ Free-Piston Shock Tube

The free-piston shock tube can be viewed as an alternate method of obtaining a high temperature and a high pressure behind the diaphragm. Essentially, a piston is driven down a cylinder by means of gas pressure. The piston compresses and heats the gas in front of it. It should be pointed out that the free-piston driver is a research tool in itself. It can be used to investigate the high pressure and high temperature gas~~es~~ produced by the compression. This is in addition to its function as a shock tube. The need for a free-piston shock tube was first expressed in October, 1962. The final design has now been completed and construction should begin shortly. The piston is 12 in~~ches~~ in diameter and has a stroke of 15 ft. Compression ratios of 150 are easily obtainable. Considerably higher compression ratios can be achieved with smaller final gas samples. By means of preheating the initial gas sample shock velocities of 30,000 fps should be easily obtainable. It may be possible to obtain cleaner operation with the free-piston shock tube than with the electrical discharge shock tube.

III. FUTURE PLANS AND DEVELOPMENTS

The capability of making equilibrium and non-equilibrium radiation measurements with the electric shock tube will be further extended. After obtaining the engineering answers needed for planetary entry, more basic investigations will be initiated. These basic investigations will be directed towards the better understanding of the high temperature gas dynamics of planetary atmospheres. Basic transport properties such as electrical conductivity, thermal conductivity and viscosity will be obtained.

The small shock tube will also be directed to studies in high temperature gas dynamics where basic transport properties can be obtained. At the present experiments on the thermal conductivity of neon are being started. Emmission studies of high temperature gases, ionization rates and vibration relaxation rates can also be studied with the small shock tube. Emmission studies of high temperature hydrogen seeded in a heavier gas might be a very fruitful field of endeavor.

The free-piston shock tube will be used first to conduct basic studies of high pressure and high temperature gases. It may later prove to be an efficient and clean method of producing shock speeds approximating 30,000 fps.

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Figure 1. Electrically Driven Clock Train


EQUIPMENT OPERATING
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Figure 3. Co[illegible] Prin[illegible]

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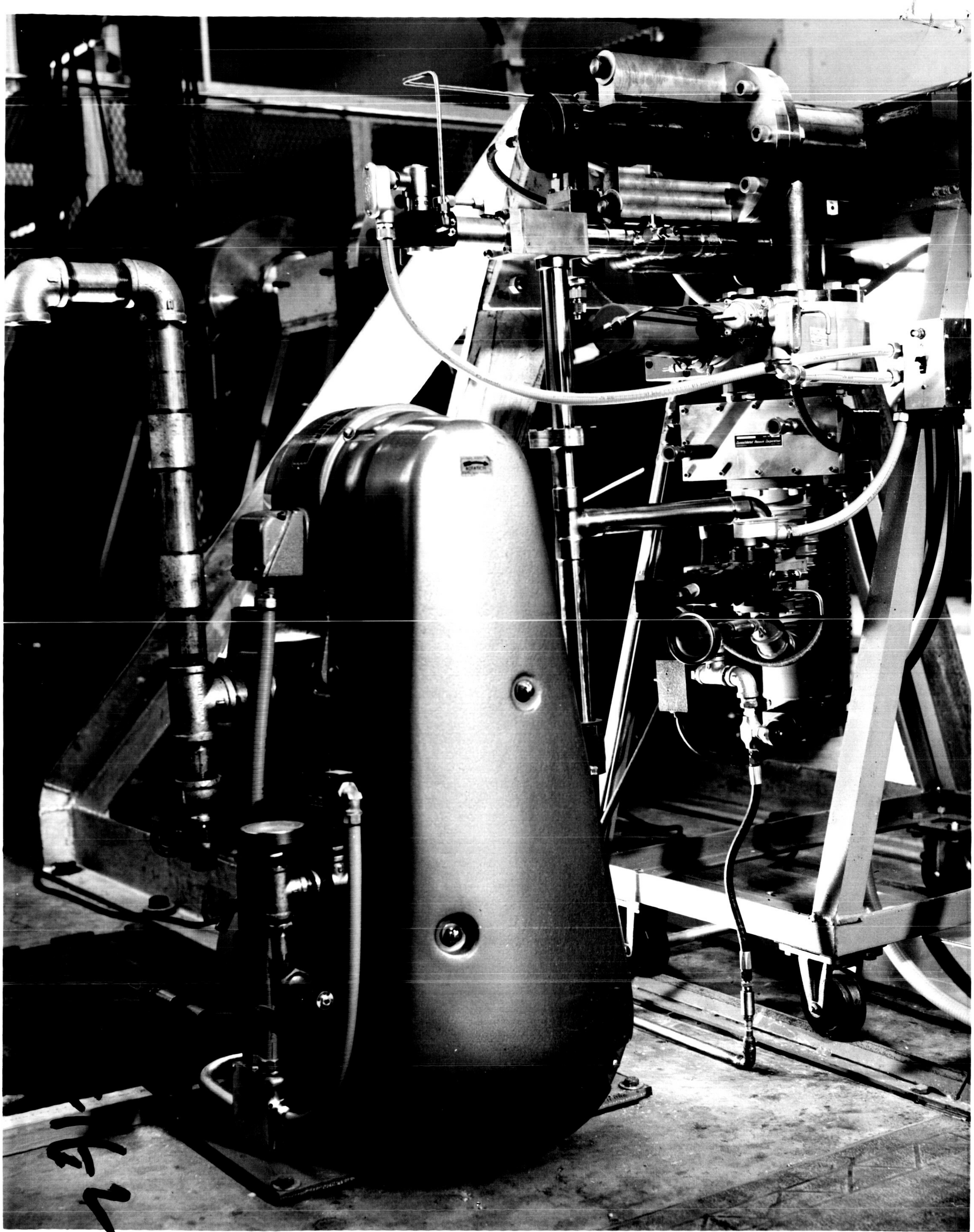
Electrically Driven Shock Tube



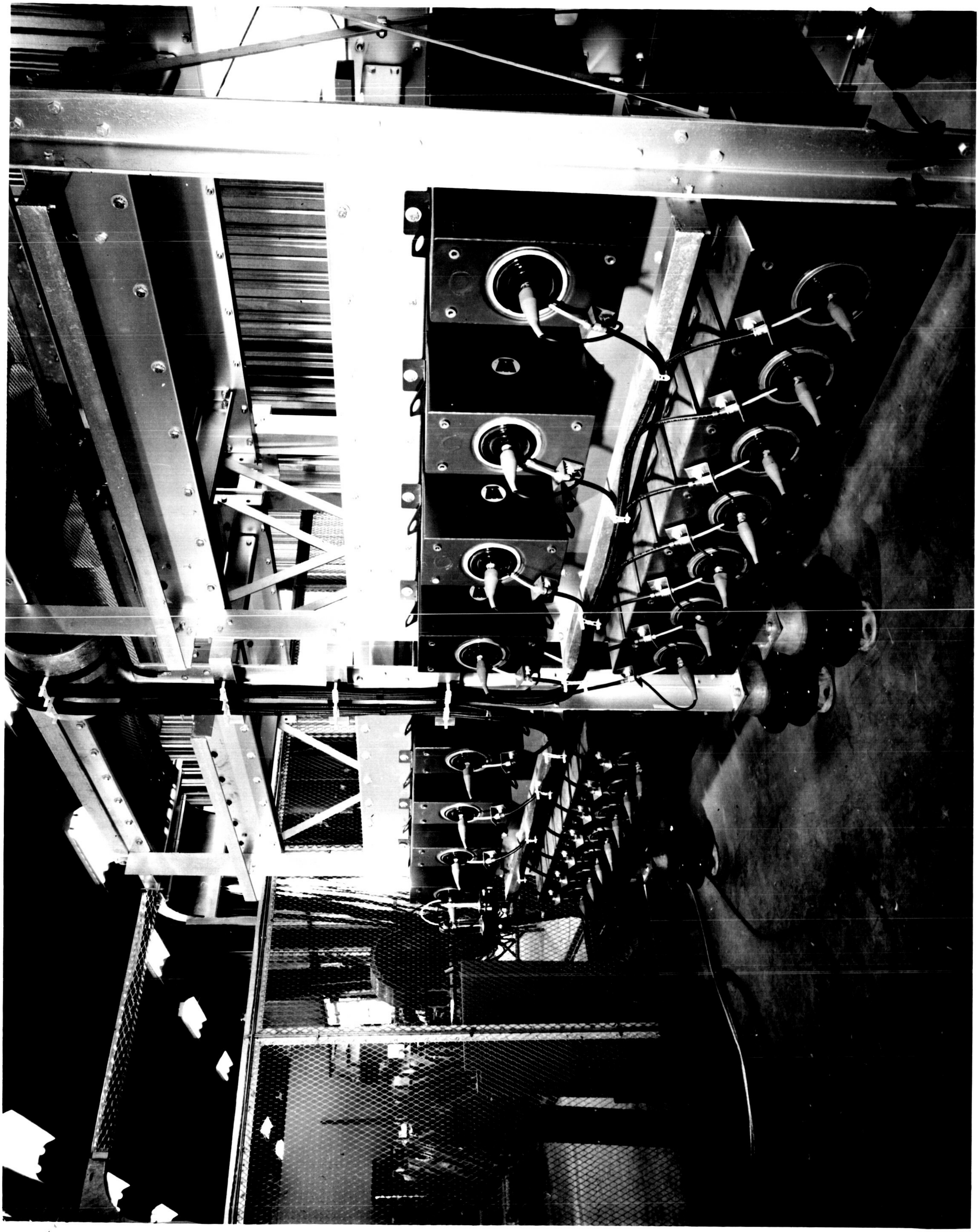


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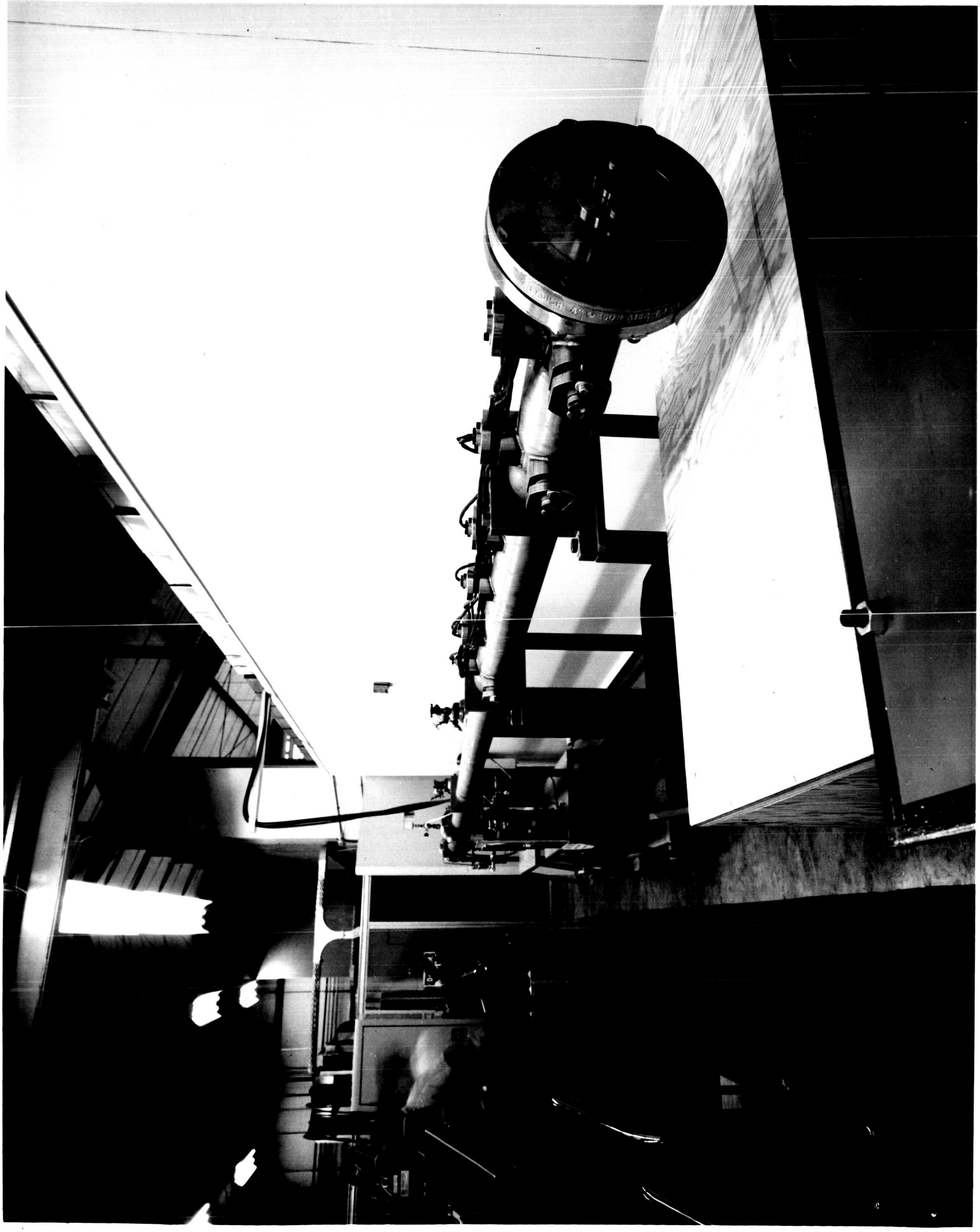
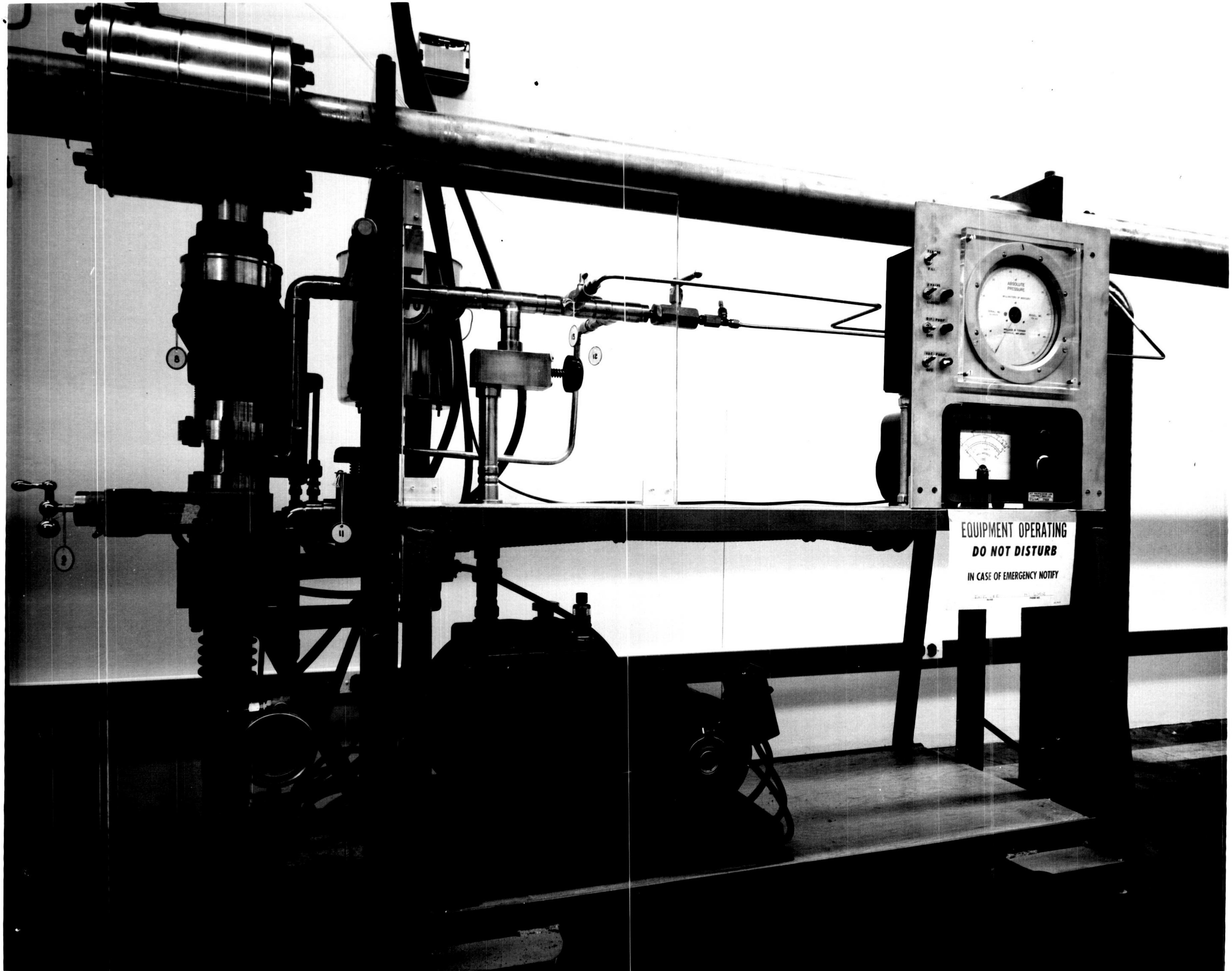
Figure 3. [illegible]

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